

CALIFORNIA DIVISION OF MINES AND GEOLOGY
FAULT EVALUATION REPORT FER-176
Helendale Fault
San Bernardino County, California
by
Michael W. Manson
May 8, 1986

INTRODUCTION

The northwest (main) segment of the Helendale fault, extending from Cushenbury Springs in Lucerne Valley northwestward to near the Kramer Hills (Figure 1), has been examined as part of CDMG's Fault Evaluation Program. Portions of this segment of the fault have been mapped by various workers (Bowen, 1954a; 1954b; Bull, 1978; Dibblee, 1960b, 1960c, 1960d, 1964a, 1972; Morton and others, 1980; Rzonka and Clark, 1982; Sadler, 1982; Thompson, 1929; Vaughan, 1922). Most of these workers provide evidence of Holocene fault rupture, but no evidence of historic surface rupture is known for the Helendale fault. Based on the available reports, and air photo evidence and field observations that are described below, several fault traces southeast of the Mojave River meet the criteria of "sufficiently active and well defined" necessary for zoning under the Alquist-Priolo Special Studies Zones Act (Hart, 1985, p. 5-6) and are recommended for zoning. The northwest end of the fault does not meet the criteria and is not recommended for zoning. An inferred connection with the South Lockhart fault (Page and Moyle, 1960) could not be verified as a surface feature, and is not recommended for zoning.

SUMMARY OF AVAILABLE DATA

The Helendale fault extends from the Mojave River area southeastward through Lucerne Valley into the San Bernardino Mountains. The fault is the westernmost of a series of subparallel, northwest-trending, right-lateral strike-slip faults in the central Mojave Desert. Figure 1 (from Jennings, 1975) shows the Helendale fault in relation to the other faults in the region. This report examines only the segment that extends for 75 km (47 miles) northwestward from Cushenbury Springs (at the southern margin of Lucerne Valley).^{*} Figure 2 shows the U.S.G.S. topographic quadrangles traversed by this segment of the Helendale fault.

Dibblee (1960b, 1960c, 1960d, 1964a, 1972) mapped the entire segment of the Helendale fault reviewed in this report (see Figure 3). He shows this northwest-trending fault to offset Jurassic and Cretaceous igneous and volcanic rocks at depth, and to be vertical or near-vertical in cross-section. The fault has a single main trace, with several branch faults. The fault is shown to offset Pleistocene and Holocene alluvium along much of its length. North of the Mojave River, the fault offsets the axis and flank of an anticline formed in Pleistocene alluvium and conglomerate. Sense of displacement at this location is southwest side down. The fault locally is concealed by Holocene alluvium, and becomes obscured by the Holocene alluvium

^{*} The 14 km-long southeast segment of the Helendale fault within the San Bernardino Mountains, and a west-trending series of faults along the north flank of the San Bernardino Mountains, will be examined in another FER.

near the river (Dibblee, 1960b). Between the Mojave River and the Sidewinder Well area, Dibblee (1960c, 1960d) shows Holocene alluvium opposite pre-Quaternary bedrock or Pleistocene alluvium along extensive segments of the fault. Locally the fault is concealed where only Holocene alluvium is present. Sense of displacement is shown as southwest side up along the vertical fault. In Fairview Valley, two faults are shown, and both are concealed by Holocene alluvium. At the northwest end of Lucerne Valley, Dibblee (1964a; 1972) shows the fault locally to be concealed by young alluvium of undifferentiated Pleistocene and Holocene age. Young alluvium is faulted near Lucerne Dry Lake and Rabbit Springs. Sense of displacement near Rabbit Springs is shown as right-lateral strike-slip. Further to the southeast, the fault again is concealed by young alluvium, but it offsets young fan deposits (Pleistocene and Holocene, undifferentiated) between Box S Springs and Cushenbury Springs. Near Cushenbury Springs, the Helendale fault has a complex junction with a west-trending series of folds and south-dipping reverse faults in bedrock and Quaternary units, and then extends southeastward into Cushenbury Canyon.

Bowen (1954a), who named the fault, mapped it within the Barstow 30' quadrangle at a scale of 1:125,000. [His mapping is more generalized than that by Dibblee (1960a, 1960b, 1960c, 1960d), and therefore his fault traces are not shown in Figure 3.] He shows the fault to have two slightly overlapping segments, with variable sense of displacement; northwest of Helendale, displacement is southwest side down, while southeast of Helendale the displacement is northeast side down. In cross section, the fault is nearly vertical and displaces the quartz monzonite bedrock (late Jurassic or early Cretaceous). He notes (p. 105) that "changes in apparent upthrown and downthrown sides from place to place along the Helendale and Harper Lake faults suggest lateral movement as well as normal movement." Bowen shows Holocene alluvium faulted along much of the length of the Helendale fault. Pleistocene alluvium is offset at the fault's northwest end (no younger deposits are present). He notes (p. 105) that recent faulting has formed scarps in the Holocene alluvium along a 10 mile (17 km) segment of the fault north and east of Sidewinder Well (see Figure 3, Apple Valley 15' quadrangle). Total displacement along the Helendale fault was not estimated by Bowen, due to the lack of markers on both sides of the fault, but he states (p. 105) that topographic expression of the fault scarps indicates that vertical displacement is greater than 400 feet (122 meters).

Vaughan (1922) mapped the (unnamed) Helendale fault in Lucerne Valley. [His generalized geologic map is at a scale of 1:125,000, and therefore his fault traces are not shown in Figure 3.] He shows the fault as displacing Quaternary alluvium, and cites (p. 397) the alignment of several springs and a slight uplift of the southwestern block as evidence for faulting. Sense of displacement along the fault is not given in his report or map, but Bowen (1954a, p. 105) cites a personal communication from Vaughan indicating that strike-slip displacement can be traced by differences in appearance between the alluvium within and outside of the fault zone.

Thompson (1929, p. 616) shows Vaughan's fault trace (which he labels the Rabbit Springs-Box S fault) on his small-scale map. He states (p. 617) that the groundwater table stands abnormally high in the vicinity of the ranch compared to areas north and east, and that several artesian wells flow on the ranch.

Page and Moyle (1960, Figure 2) infer that the Helendale faults extends northwestward as a "right step-over" to connect with the South Lockhart fault. They do not discuss these faults in their text, but they show the Helendale fault to be the westernmost of two northwest-trending, parallel faults in Pleistocene alluvium (see Figure 3, Hawes 15' quadrangle). Their map is based upon a generalization of then-unpublished mapping by Dibblee (1960b). However, Dibblee (1968, p. 43) states that the South Lockhart fault, which also offsets Pleistocene alluvium, dies out in the Hawes [15'] quadrangle.

Hollenbaugh (1968) mapped the geology of the Cushenbury Springs region at a scale of 1:12,000. The Helendale fault is shown as a linear northwest-trending, "approximately located" surface feature in Holocene alluvium, Pleistocene(?) fanglomerate, and Mesozoic and Paleozoic bedrock units. Selected traces from his map are shown on Figure 4. Hollenbaugh states (p. 75) that the Helendale fault is the largest and most recently active of a series of subparallel faults along the margin of the San Bernardino Mountains within his study area. The fault plane is shown in cross section to be vertical, and the sense of displacement is "right-lateral, northeast side down" (p. 75). According to Hollenbaugh, the shear zone contains several traces, and is 200 feet [60 meters] wide at the mouth of Cushenbury Canyon, narrowing to 30 feet [9 meters] wide further to the southeast. On his map, the Helendale fault truncates several south-dipping thrust faults, and southeast of Cushenbury Springs it juxtaposes Holocene alluvium and Pleistocene(?) fanglomerate. His "approximately located" trace in Holocene alluvium west of Highway 18 could not be verified on the air photos (see Figure 4).

Rzonka and Clark (1982) show the geology in the immediate area of the plant and quarry at Cushenbury Springs, with the Helendale fault in a location similar to that shown by Hollenbaugh (see Figure 4). Their map includes two west-trending, south-dipping thrust faults (not shown on Figure 4) which branch off of the Helendale fault at the mouth of Cushenbury Canyon. They state (p. 679) that the right-lateral, strike-slip Helendale fault is actively displacing "very young sediments".

Riley (1956, p. 5) conducted "very brief reconnaissance mapping" in the Lucerne Valley area for his groundwater study. His location for the Helendale fault is approximately the same as Dibblee's (see Figure 3). An inferred, concealed extension of the fault is shown along the northeast flank of the hill at Box S Springs. A parallel, concealed fault is shown to cross the southwest end of Lucerne Lake (these faults are not shown on Figure 3).

Schaefer (1979) conducted a subsurface hydrologic study of Lucerne Valley. He generalized the mapping of Dibblee (1964a) and Riley (1956), and used their fault locations. He also shows an inferred, concealed, south-eastern extension of Riley's Lucerne Lake fault (not shown on Figure 3). The extension is based on offset groundwater levels, which he traced as far south as Highway 18 (p. 7, 13). Although not discussed by Schaefer, the inferred fault may offset Pleistocene alluvium at depth.

Morton and other (1980) used black and white, low-sun-angle air photos to produce their photo reconnaissance map of fault-related features along the northwest segment of the Helendale fault (see Figure 4). Their annotated strip map shows alignments of scarps and tonals in alluvium, and alignments of notches in bedrock along the general trend of the fault as mapped by Dibblee. However, they did not field-check the geomorphic features. Their data are plotted on 1:24,000-scale maps, and comprise the most important single source of information on recently-active traces of the Helendale fault. Most of the fault-related features shown by Morton and others were verified by photo inspection and field inspection during this study (see Figure 4 and p. 10-12, below). Annotations such as "Eroded ... scarp, appears to cut all but youngest alluvium", suggest that the fault has been active in Holocene time.

Sadler (1981) mapped portions of twelve 7.5' quadrangles in the northeast San Bernardino Mountains. In the south Lucerne Valley area, numerous bedrock faults are shown as being concealed by Holocene alluvium (see Figure 4). [Sadler does not use a "concealed" symbol except for "growth faults" -- faults which offset the base but not the top of older alluvial fan deposits.] Active fan surfaces and drainages are not shown to be faulted, although relict fan surfaces [the youngest of which may be early Holocene in age], Tertiary sandstone, and Mesozoic granitic rocks are shown to be offset or truncated. Two relict fan deposits and an active drainage appear to be right laterally offset at Box S Springs. North of the substation, a relict fan surface [latest Pleistocene-early Holocene?] is shown to be truncated by the Helendale fault. However, the bedrock faults or joints shown by Sadler adjacent to the mouth of Cushenbury Canyon generally are not confirmed by Dibblee (1964a), Hollenbaugh (1968), Rzonka and Clark (1982), or by my air photo interpretation. Sadler does not show the main trace of the Helendale fault or most of the other faults in the vicinity of the Kaiser quarry and plant (see Figures 3 and 4).

Bull (1978) includes a reconnaissance appraisal of Quaternary tectonic activity along the Helendale fault. He uses five differential equations, which interrelate uplift, erosion, and deposition along streams that cross mountain fronts, to divide major mountain ranges along the fault into one of three classes of terrain. According to Bull (1978, p. 33), Class 1 ["active"] fronts occur in highly active tectonic settings that are generally characterized by active folding and/or faulting during the Holocene as well as the Pleistocene. Class 2 ["slightly active"] faulted mountain fronts generally have ruptured Pleistocene, but not Holocene, geomorphic surfaces. *** Class 3 ["inactive"] mountain fronts, by definition, have been tectonically inactive during the Quaternary." Of the seven range fronts along the Helendale fault that are analyzed by Bull (p. 182-183), five are classified as "active", one is classified as "slightly active", and one is classified as "inactive" (see Figure 3). He gave no definite evidence of Holocene faulting.

In his summary and conclusions (p. 161) Bull noted the following information:

"Holocene and latest Pleistocene geomorphic surfaces can be differentiated because of climate-controlled changes in the modes of

operation of the arid fluvial systems. Below altitudes of about 1,200 m, the latest Pleistocene surfaces are characterized by well sorted gravels, smooth, brownish-black desert pavements, argillic B soil horizons, and depths of C_{ca} horizons of about 0.3 m. Holocene surfaces consist of poorly sorted bouldery gravel, bar-and-swale topography, brown varnish, a lack of argillic soil horizons, and depths to C_{ca} horizons of about 0.1m. Locally, basalt flows and playas have been ruptured during the Holocene, and earthquake-caused rockfalls onto Pleistocene and Holocene geomorphic surfaces are common next to fault scarps, but are absent on nearby steep slopes that are not adjacent to active faults."

His criteria for distinguishing between latest Pleistocene and Holocene surfaces were extensively used by me during my field inspections for this and other reports (see "Air Photo Interpretations and Field Observations", below).

The sense and total amount of displacement along the Helendale fault are still uncertain. Dibblee (1961, p. B-197) hypothesizes that "metavolcanic rocks" [presumably the latitic porphyry and associated rocks shown in his maps of the Victorville and Apple Valley quadrangles] have been right-laterally offset "several miles" along the fault. Church and others (1974 p. 688) state that as much as 0.5 meter of sharply-defined vertical movement has been measured across the Helendale fault since 1906, and that this surface deformation "is consistent with right-lateral motion and under thrusting beneath the north margin of the San Bernardino Mountains." Garfunkel (1974, p. 1934) estimates that 10 to 15 km of right-lateral, strike-slip displacement has occurred along the fault, based on locations of Paleozoic marine sedimentary rocks north and east of Victorville. Miller and Morton (1980, p. 22) disagree with Garfunkel's estimate; they believe that total right-lateral offset of a 75 million-year-old pluton near Interstate Highway 15 amounts to only 1 or 2 km. They also cite mapping by Dibblee (1960c), which shows approximately 6 km of right-lateral displacement of a Mesozoic(?) quartz monzonite body (west) of Sidewinder Well. They concede, however, that the quartz monzonite bodies may not be offset portions of the same deposit.

AIR PHOTO INTERPRETATION AND FIELD OBSERVATIONS

My air photo interpretations and field observations are included in Figure 4, which is a photoreconnaissance map of young-looking fault features along the Helendale fault by Morton and others (1980, sheet 1). I used their strip map as a base for my data because it shows apparently fault-related geomorphic features on a suitable-scaled topographic map. In general, the features noted by Morton and others were verified during this study, and are accurately located. However, some features shown by them were not verified.

Three sets of black-and-white air photos were available to me: U.S.G.S., 1945, series SA; U.S.B.L.M., 1977, series CA93-77; and U.S.B.L.M., 1978, series CAHD-77. Only a few of the 1945 air photos were used in this study; specifically, only those photos which covered the Cushenbury Springs and Rabbit Springs areas of Lucerne Valley, where recent development may have obliterated the subtle geomorphic features. The low-sun-angle air photos used by Morton and others were not available. Field inspections of the Helendale fault were made by me on January 15 and February 3-7, 1986. Earl Hart and William Bryant, C.D.M.G., assisted me in field work on January 15. Earl Hart assisted in air photo interpretation.

For the purpose of discussion in this report, the Helendale fault may be divided into two segments, with the "dividing point" located approximately 4 km (2.5 miles) northwest of the fault's intersection with Interstate Highway 15. Northwestward from this point, the Helendale fault is difficult to locate, and evidence of recent faulting is sparse and very discontinuous (see Figure 4, Locations 1-10). No air photo evidence of faulting was seen in the Holocene alluvium along the Mojave River, nor was there air photo evidence of faulting in the latest Pleistocene and Holocene alluvial fans along the projected trace of the fault. At the northwest end of the fault is an alignment of southwest-facing, low (.5-1.0 meter), truncated spurs in Pleistocene conglomerate (Locations 3-4). These aligned, truncated spurs are on the southwest flank of a low anticline mapped by Dibblee (1960b), have well-rounded crests, and a very low (est. 5°-10°) scarp angle. Holocene alluvium in the narrow, intervening gulleys is light brown beneath the surface, and contrasts markedly with the orange-colored soil developing on the conglomerate.

Southeast of the "dividing point" shown on Figure 4, the active trace of the Helendale fault can be followed as a northwest-trending, somewhat discontinuous alignment of geomorphic features in bedrock and late Pleistocene and Holocene alluvium (see Figure 4, Locations 11-50). These fault-related features include scarps, tonals, right-laterally-offset drainages and ridges, linear drainages and breaks-in-slope, and shutter ridges. Right-lateral strike-slip displacement is clearly indicated by these features. Although the fault scarps often are prominent in the air photos, the fine details associated with active faulting are absent where the scarps were visited in the field. No sag ponds or mole tracks, and very few deflected drainages were noted in the young alluvium at the base of individual scarps. The alluvium is usually a light brown color beneath the surface. It shows little or no soil development and generally lacks clay films on individual grains, indicating that the alluvium is Holocene in age. Caliche deposits were noted near Cushenbury Springs, Box S Springs (Location 47), and in the roadcut for the Mojave Northern Railroad at Black Mountain (Locations 23-24), but all of these sites are in limestone-rich alluvial fans that probably contain calcite-rich ground water. [Adjacent source areas of these fans contain active limestone quarries.] Segments of the fault are largely concealed by young alluvium in Fairview Valley, and in Lucerne Valley between Old Woman Springs Road and Meridian Road. As shown on Figure 4, some of the fault traces shown by Hollenbaugh (1968) and Sadler (1982) near Cushenbury Springs could not be verified on the air photos.

SEISMOLOGY

An examination of 'A' and 'B' quality epicenter locations for earthquakes from 1969 to 1984 (CalTech, 1985) shows that, except for quarry blasting for the various mining companies near the Helendale fault, no epicenters were located on the fault (see Figure 5). A number of earthquakes had epicenters within 2 or 3 km of the fault. No seismicity was recorded for the fault segment north of Black Mountain.

CONCLUSIONS

The Helendale fault is a major, right-lateral, strike-slip fault which extends 75 km (47 miles) northwestward from Cushenbury Canyon to the Mojave River area. The fault is the westernmost of a series of subparallel, closely-spaced faults in the central Mojave Desert (Figure 1), and has a complex

junction with reverse faults along the northern base of the San Bernardino Mountains. Various workers disagree as to the amount of right-lateral displacement since Cretaceous time, with estimates ranging from 1 or 2 km up to 15 km. In terms of recency of faulting, the Helendale fault may be divided at a point 4 km (2.5 miles) north of the fault's intersection with Interstate Highway 15 (Figure 4). Northwest of the dividing point, evidence of recent faulting is sparse and very discontinuous. The inferred connection of the Helendale fault with the South Lockhart fault to the northwest (Page and Moyle, 1960) could not be confirmed as a surface feature. Southeast of the dividing point, active traces of the Helendale fault can be followed as discontinuous alignments of scarps, tonals, right-laterally-offset drainages and ridges, linear drainages and breaks-in-slope, and shutter ridges. In Lucerne Valley, the fault locally is shown to offset alluvium of undifferentiated Pleistocene and Holocene age (Dibblee, 1964a) or Holocene age (Hollenbaugh, 1968, Rzonka and Clark, 1982). At other locations, Dibblee (1960b, 1960c, 1960d, 1972) shows the fault to juxtapose bedrock or Pleistocene alluvium against Holocene alluvium, and locally to be concealed by Holocene alluvium. My field inspections of the fault between the "dividing" point and Cushenbury Canyon indicate the fault locally is concealed only by very young alluvium that has little or no soil development, and usually no desert varnish on surficial material.

RECOMMENDATIONS

The southeast segment of the Helendale fault, from the northern part of the Big Bear City quadrangle to a point 4 km (2.5 miles) northwest of the fault's intersection with Interstate Highway 15, meets the necessary criteria of "sufficiently active and well-defined" necessary for zoning, and should be zoned as shown in Figure 6 of this report. References to be cited are Morton and others (1980, sheet 1), and this report for fault location and recency. Dibblee (1960c, 1960d, 1964a, 1972) should also be cited for confirmation, although his specific traces were not used. The segment of the Helendale fault northwest of the dividing point, including its inferred connection with the South Lockhart fault, does not meet the criteria necessary for zoning, and should not be zoned. Zoning recommendations near Cushenbury Springs should be deferred until the completion of studies (currently underway) of the North Frontal fault zone.

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*I concur with the
recommendations.
Earl W. Hart*

*5/12/86
Note minor changes in Fairview
Valley quad (Fig. 4 & 6) -- EWA, 7/15/87*

REFERENCES

- Bowen, O.E., Jr., 1954a, Geology and mineral deposits of Barstow [30'] quadrangle, San Bernardino County, California: California Division of Mines Bulletin 165, 208 p., 8 plates, scale 1:125,000.
- Bowen, O.E., Jr., 1954b, Geology of the Barstow area, San Bernardino County: California Division of Mines Bulletin 170, Map Sheet 18, scale 1:125,000.
- Bull, W.B., 1978, Tectonic geomorphology of the Mojave Desert, California: U.S. Geological Survey Technical Report 14-08-0001-G-394, 188 p.
- California Institute of Technology, 1985, CALNET earthquake data (preliminary).
- Church, J.P., Castle, R.O., Clark, M.M., and Morton, D.M., 1974, Continuing crustal deformation in the western Mojave Desert: Geological Society of America Abstracts with Programs, vol. 6, no. 7, p. 687-688.
- Dibblee, T.W., Jr., 1960a, Geologic map of the Barstow [15'] quadrangle, San Bernardino County, California: U.S. Geological Survey Mineral Investigations Field Studies Map MF-233, scale 1:62,500.
- Dibblee, T.W., Jr., 1960b, Geologic map of the Hawes [15'] quadrangle, San Bernardino County, California: U.S. Geological Survey Mineral Investigations Field Studies Map MF-226, scale 1:62,500.
- Dibblee, T.W., Jr., 1960c, Preliminary geologic map of the Apple Valley [15'] quadrangle, California: U.S. Geological Survey Mineral Investigations Field Studies Map MF-232, scale 1:62,500.
- Dibblee, T.W., Jr., 1960d, Preliminary geologic map of the Victorville [15'] quadrangle, California: U.S. Geological Survey Mineral Investigations Field Studies Map MF-229, scale 1:62,500.
- Dibblee, T.W., Jr., 1961, Evidence of strike-slip movement on northwest-trending faults in Mojave Desert, California, in Geological Survey Research, 1961 - Short papers in the geologic and hydrologic sciences, Articles 1 - 146: U.S. Geological Survey Professional Paper 424B, p. B-197 - B-199.
- Dibblee, T.W., Jr., 1964a, Geologic map of the Lucerne Valley [15'] quadrangle, San Bernardino County, California: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-426, 6 p., (scale 1:62,500.
- Dibblee, T.W., Jr., 1964b, Geologic map of the Ord Mountains [15'] quadrangle, San Bernardino County, California: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-427, 6 p., 1 plate, scale 1:62,500.
- Dibblee, T.W., Jr., 1968, Geology of the Fremont Peak and Opal Mountains [15'] quadrangles, California: California Division of Mines and Geology Bulletin 188, 64 p., 4 plates.

REFERENCES Continued

- Dibblee, T.W., Jr., 1972, Geologic map of the Lake Arrowhead [15'] quadrangle, California: U.S. Geological Survey unpublished map, scale 1:62,500.
- Garfunkel, Z., 1974, Model for the late Cenozoic tectonic history of the Mojave Desert, California, and for its relation to adjacent regions: Geologic Society of America Bulletin, v. 85, p. 1931 - 1944.
- Guillou, R.B., 1953, Geology of the Johnson Grade area, San Bernardino County, California: California Division of Mines Special Report 31, 18 p., 1 plate, scale 1:24,000.
- Hart, E.W., 1985, Fault-rupture hazard zones in California: California Division of Mines and Geology Special Publication 42 (Revised), 24 p.
- Hollenbaugh, K.M., 1968, Geology of a portion of the north flank of the San Bernardino Mountains, California: unpublished Ph.D. thesis, University of Idaho, 109 p., 1 plate, scale 1:12,000 (C.D.M.G.'s copy of the map is reduced to approximately 1:20,571).
- Jennings, C.W., 1975, Fault map of California, with locations of volcanoes, thermal springs, and thermal wells: California Division of Mines and Geology Geologic Data Map Sheet Number 1, scale 1:750,000.
- Miller, F.K., and Morton, D.M., 1980, Potassium-Argon geochronology of the eastern Transverse Ranges and southern Mojave Desert, Southern California: U.S. Geological Survey Professional Paper 1152, 30 p., 1 plate, scale 1:512,800 (approximate).
- Morton, D.M., Miller, F.K., and Smith, C.C., 1980, Photoreconnaissance maps showing young-looking fault features in the southern Mojave Desert, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1051, 7 plates, scales 1:24,000 and 1:62,500.
- Page, R.W., and Moyle, W.R., Jr., 1960, Data on water wells in the eastern part of the middle Mojave Valley area, San Bernardino County, California: California Department of Water Resources Bulletin 91-3, 223 p., 2 plates.
- Riley, F.S., 1956, Data on water wells in Lucerne, Johnson, Fry, and Means Valleys, San Bernardino County, California: U.S. Geological Survey Open-File Report, 150 p., 1 plate, scale 1:93,750.
- Rzonca, G.F., and Clark, D.W., 1982, Local geology, Kaiser Cement Corporation, Cushenbury facility, Lucerne Valley, California, in Fife, D.L., and Minch, J.A., editors, Geology and mineral wealth of the California Transverse Ranges: South Coast Geological Society, Inc., Annual Symposium and Guidebook Number 10, p. 676-679.

REFERENCES Continued

- Sadler, P.M., 1981, The structure of the northeast San Bernardino Mountains: Notes to accompany 7.5 minute quadrangle maps submitted for compilation onto the San Bernardino 1 X 2° quadrangle: Final report to State of California, Department of Conservation, Division of Mines and Geology, Contract #5-1104, 26 p. + appendix (unpublished data).
- Sadler, P.M., 1982, Geology of the northeast San Bernardino Mountains, San Bernardino County, California: California Division of Mines and Geology Open-File Report 82-18 LA, 25 sheets, scale 1:24,000.
- Schaefer, D.H., 1979, Ground-water conditions and potential for artificial recharge in Lucerne Valley, San Bernardino County, California: U.S. Geological Survey Water-Resources Investigations 78-118, 37 p.
- Thompson, D.G., 1929, The Mohave Desert region, California: U.S. Geological Survey Water-Supply Paper 578, 759 p., 34 plates.
- U.S. Bureau of Land Management, 1977, black-and-white air photos, scale 1:30,000, series CA93-77, flight line 1, photos 5-9; flight line 2, photos 1-6.
- U.S. Bureau of Land Management, 1978, black-and-white air photos, scale 1:30,000, series CAHD-77, flight line 7L-24, photos 19-23; flight line 7L-25, photos 18-21; flight line 7L-26, photos 14-18; flight line 7L-27, photos 11-15; flight line 7L-28, photos 10-14; flight line 8L-29, photos 2-10; flight line 8L-30, photos 3-10; flight line 8L-31, photos 2-10.
- U.S. Geological Survey, 1945, black-and-white air photos, scale 1:24,000, series S.A., flight line 3, photos 58-60, 70, 71; flight line 4, photos 40-43.
- U.S. Geological Survey, 1979, Index to topographic maps of California, scale 1:1,000,000.
- Vaughan, F.E., 1922, Geology of San Bernardino Mountains north of San Geronio Pass [California]: University of California Publications, Bulletin of the Department of Geological Sciences, v. 13, no. 9, p. 319-411, 1 map, scale 1:125,000.

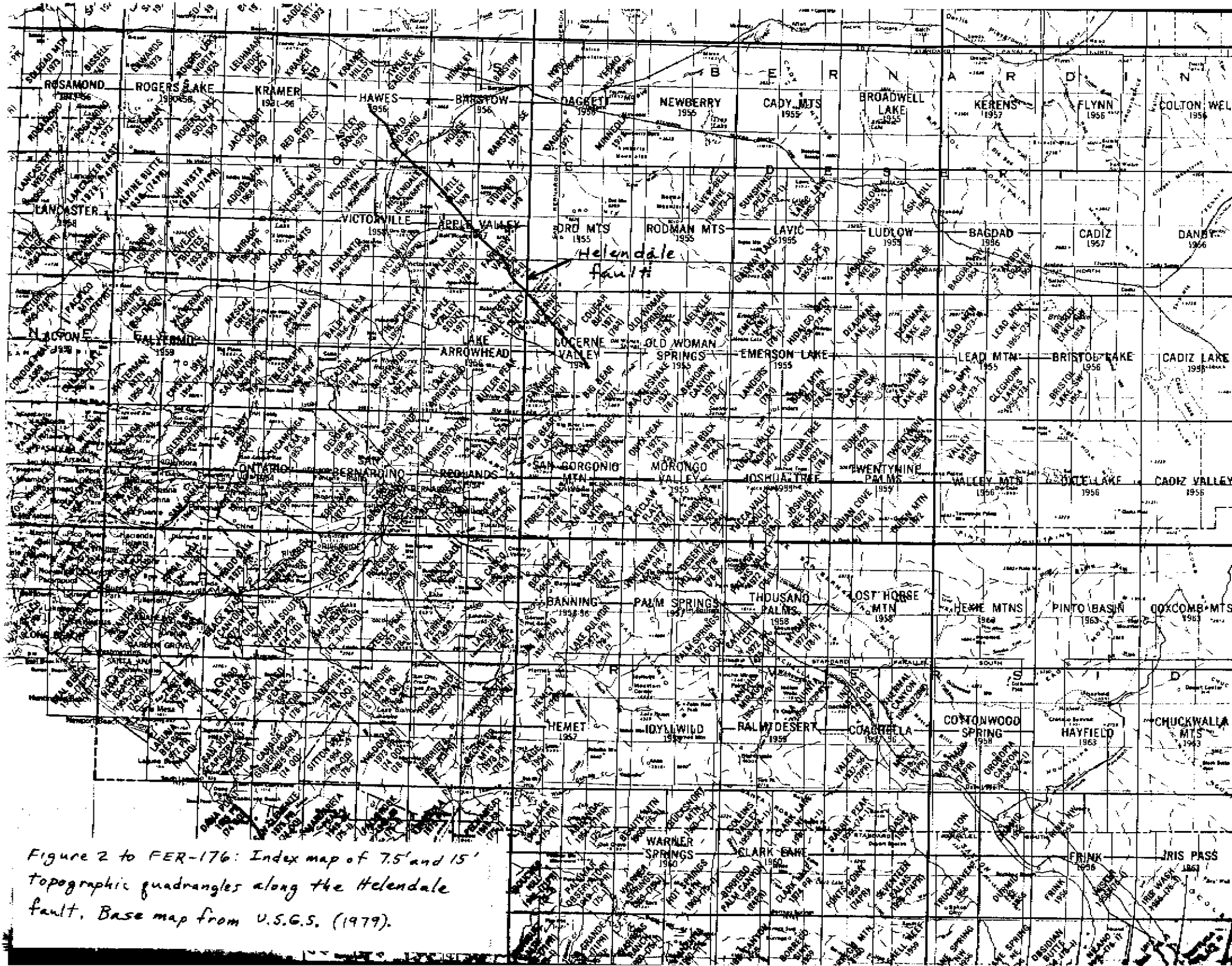


Figure 2 to FER-176: Index map of 7.5' and 15' topographic quadrangles along the Helendale fault. Base map from U.S.G.S. (1979).

EARTHQUAKES M1.0 OR GREATER

CIT 1969-1984 AB QUALITY ONLY

SAN BERNARDINO SHEET

TRANSVERSE MERCATOR PROJECTION

SCALE = 1/250000

MAGNITUDE

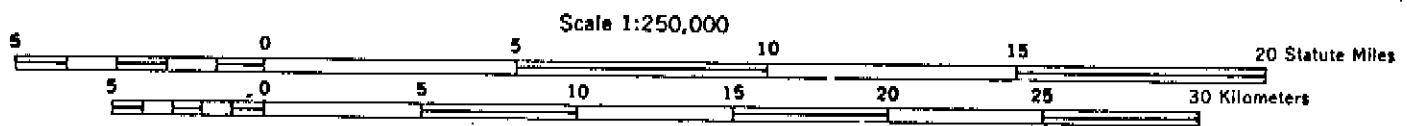
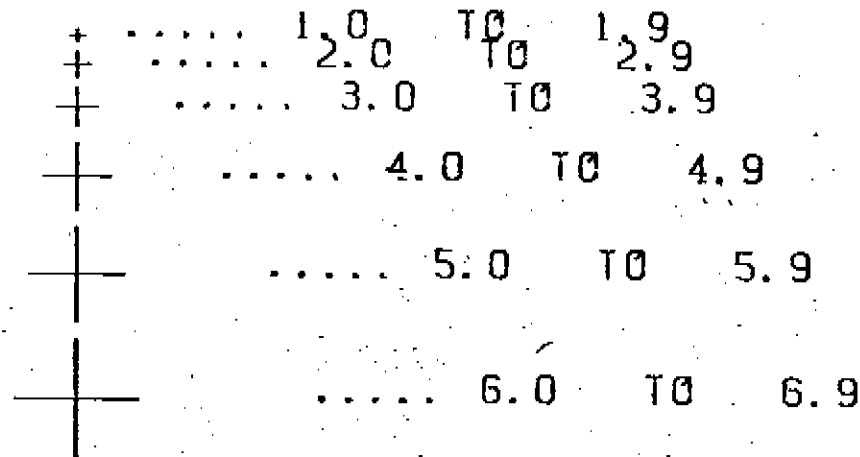


Figure 5 to FER-176: Epicenter locations near the Helendale fault for the period 1969-1984 (CalTech, 1985).

Figure 5 to IER-176
(All Reverse side)

